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MARS - A TARGET FOR ADVANCED PROPULSION

by
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The subject of this conference makes me think back to a luncheon in Gatlinburg, Tennessee, in May of 1961 at which I also was the guest speaker. At that time we were awaiting Shepard's suborbital flight. The Russians had launched several very high payload satellites weighing about 10,000 to 14,000 pounds. In April of 1961, Gagarin had made the first manned orbital flight. Many of us in NASA and, I am sure in the entire aerospace community and probably throughout the world, were also at that time awaiting a

-morepolicy decision from the President on space program objectives. In my Gatlinburg speech I tried to anticipate the goals that the President might set in our space program and I tried to consider the alternatives that were available. My conviction was then, and still is today, that space represents an area of visible technological and scientific strength in which the United States must demonstrate superiority. In currently used terminology we must demonstrate preeminence in space.

In my Gatlinburg talk I referred to a speech that the President had made before the newspaper publishers in New York the previous week. He was talking about the challenge to our way of life when he said, "whatever our hopes may be for the future ..... for reducing this threat or living with it ..... there is no escaping either the gravity or the totality of its challenge to our security and survival ..... a challenge that confronts us in unaccustomed ways in every sphere of human activities." Although details may have changed since then, I think the basic premise in that quotation is still correct and I am convinced that space represents one of the many areas in which we must meet the challenge and achieve demonstrable preeminence.

In was true two years ago and I believe it is still true that none of us in the space business and none of the people in this country could or would tolerate a situation in which we would indefinitely and possibly forever be watching someone else perform the dramatic missions in space, making the dramatic discoveries in space, while we tagged along indicating either that we don't think it's important enough to drive into space, or else, after much delay, we would come along to duplicate the mission and say, "See, we can do it too." I don't think any of us would have tolerated the situation which existed two years ago when the Russians were repeatedly launching heavy payloads (and they still are), and when the Russians had already launched the first man in space if we could not look forward to the time that we could ourselves have established superiority or preeminence. A country that is always second best in so obvious an area of scientific and technological achievement would certainly suffer a serious loss in morale, leadership, strength, and respect. I don't think we have ever had any choice but to accept the challenge and make the effort necessary to assure obvious preeminence.

Accepting this premise, I presented two possible mission goals in my Gatlinburg talk: one was manned landing and exploration of the moon; the other was manned landing and exploration of Mars. I indicated my personal preference for aiming at the Mars mission because it would be further off in time and with what I believe to be a lead in nuclear rocket propulsion, would give us a greater chance of taking a clear lead in space. Another reason for my thinking was that developing the capability to do the Mars mission would automatically develop a capability to do the lunar mission, so we could do that as a logical part of an effort aimed at the planets.

The President's address to Congress on national goals came a little over two weeks later. In that address the President specified the manned lunar landing mission in this decade as our major space objective. He also included as one of four major items emphasis on the ROVER nuclear rocket program because it offered a capability for missions beyond the moon.

I believe that the speed with which the lunar mission program has been undertaken, the major decisions that have been made in regard to the mode of operation and the vehicles to be used, the selection of launch site and test and fabrication facilities, the selection of development contractors, and the establishment of a total organization for executing the program give us good reason to hope that we will be first in the landing of men on the moon, within this decade. In essence, there is a strong belief, and I agree, that the manned lunar program is sufficiently far off, it has been started rapidly enough, and the technology is well enough developed to give us reasonable assurance that we can demonstrate our superiority in space through the accomplishment of this mission within this decade.

It is important, however, as is being done at this conference, for all of us to think ahead to the next possible steps in space. We have in the past misjudged most areas of new technological development and we have frequently underestimated the progress in those areas. We must accept as inevitable the fact that we now stand near the center of a fairly small circle of knowledge on space and that, as we explore out to its circumference, we will find more and more things to learn and do as part of a circle of ever increasing radius. It is important that we have some feel for the missions that are logical follow-on to the manned lunar landing mission so that we may prepare the basic information, the understanding, the technology, and the hardware that will eventually be required to perform these advanced missions in a reasonable time without the need for excessive crash efforts. We must never permit outselves to come up against the stone wall of inadequate research information that prevents our taking the logical next step aimed at continued learning and continued progress. It is, therefore, necessary that we look to the evaluation of advanced missions in order to determine the kind of hardware, the kind of technology, and the kind of research that is required to answer the unknowns.

The accomplishment of missions to Mars will require the development of new propulsion systems, new rockets, new spacecraft, and new technology in all these areas. It will require an understanding of space shielding, meteoroid protection, propellant storage, guidance and control, better information on the planet, and development of the launch complexes, etc. It will be a very major undertaking exceeding the Apollo program in total cost and difficulty. For that reason, we must realistically recognize that one of the factors determining the timing of such a mission will be the availability of funds and manpower. We must recognize that we cannot undertake such a mission until the Apollo mission begins to phase out.

If, as will probably be the case, rendezvous in earth orbit and some orbital assembly or propellant transfer will be required to perform the Mars landing missions, an earth orbiting space laboratory will probably precede the accomplishment of the actual planetary missions. The cost of such a system would also be high but it would probably be a necessary stepping stone to the planetary missions. Therefore, if we direct our long range attention to the performance of the manned Mars mission, we will be providing the capability for many other missions of interest.

I am not convinced, however, that funding will itself set the pace of a Mars mission because the unknowns in such a mission will require the accumulation of a great deal of basic information and it will require substantial development efforts for all of the systems and facilities that would be required in such a mission. I think it is to be expected that the time required for development of these systems puts the accomplishment of a manned Mars landing mission off until late in the seventies and more probably into the early eighties. This may come as a shock to many of the so-called planners whose reports talk of what would be required to do a manned planetary mission in 1971 to 1973. I think that in their hope to sell the mission they are completely fooling themselves as to the complexity and difficulty of the overall mission. Unfortunately there are many people within the Government who propose that contractors aim their work at evaluating what would be required in the way of development efforts and development programs to achieve major portions of planetary mission systems in the early seventies. As is always the case, we would be much wiser and surer of accomplishing such a mission at the earliest possible time if we realistically recognize the difficulty of the job and proceed aggressively and logically to accumulate the technology in all of the areas of uncertainties in the development of the systems needed to perform such a mission so that we can better plan and program the mission.

How will the planetary mission be accomplished? Considering only the propulsion part of the system, I am convinced that nuclear propulsion will be used in the upper stages. More specifically, I expect that large chemical rocket booster stages, in combination with nuclear rocket upper stages, will be used to accomplish the Mars landing mission. I expect also that such vehicles and propulsion systems will be used to perform the preliminary missions of manned fly-by trips around Mars and trips into orbit around Mars. It is conceivable that such missions could start in the latter part of the 70's. I am sure that talks given in this conference have already presented, or will present the advantages of nuclear rockets for such missions, or they have tacitly assumed their use.

I would like to take the rest of the time available to me to consider some of the propulsion systems that are being considered for Mars missions and that have been suggested for Mars missions. Rather than going into specific descriptions of the work going on, I would like to generally present my thoughts on these various propulsion systems.

The propulsion systems that are now available to us are essentially the low specific impulse chemical rocket systems, relying upon various solid propellants and upon the use of kerosene and oxygen. As a logical step, following extensive research effort within the Government and in some industrial groups, considerable effort is now being directed toward developing chemical rocket systems using hydrogen-oxygen as the propellant combination. It is my personal opinion, not supported by any agency approval or planning, that hydrogen-oxygen will be used in the launch stages of the large vehicles needed to place about a million pounds into earth orbit preparatory to rendezvous, assembly, and propellant transfer for the nuclear rocket propelled Mars trip. It is interesting to point out that the development and mission application and our major dependence upon successful development of hydrogen-oxygen in Centaur, Saturn I, Saturn IB, and Saturn V was initiated on the basis of the research work and ground test work that had been done. There is today no flight experience with this propellant combination. There is, however, very successful ground test operation of engines using hydrogen-oxygen as the propellant combination. I emphasize this point because it indicates that where the new system is a logical follow-on to existing information and offers significant performance advantages, developments are undertaken without the need for flight demonstration. What is needed, however, is substantial research effort and ground test experience to assure that the technology is understood and that hardware can be developed.

I maintain that the nuclear rocket is the next logical step in rocket propulsion. The turbopumps, nozzles, gimbal bearings, thrust structure, valving, vehicle structure, guidance systems, are all logical follow-on developments based to a very large extent on technology available in chemical rocket practice. In addition, the methods of developing these components and systems rely heavily on techniques developed in chemical rocket practice. What is new in these "non-nuclear" components is the radiation environment and, in certain cases, an extrapolation to higher heat fluxes or flow capacity. This does not, in my opinion, involve the development of new technology. It does involve extending the knowledge provided for similar components in the chemical rocket system into new ranges of operating conditions. This may, of course, involve new fabrication techniques, different materials, elimination of radiation sensitive equipment and materials, but is still not new in terms of requiring an entirely new technology.

The major new item in the nuclear rocket is of course the nuclear reactor. I am confident that such a reactor can be developed and that it will result from the program we are pursuing. We are aiming our program at providing this new reactor technology and at defining, through a careful research and technology development effort, the boundary conditions within which we can design and operate these reactors, so that they may, with confidence, be planned for in application to various space missions. I am convinced that as soon as successful reactor operation has been achieved, the practicability, developability and performance potential of nuclear rockets will be generally accepted and will be relied upon in all new vehicle developments and in extending the payload capability of the Saturn V vehicle.

An important question to explore then is, what is the current status of the reactor part of the program? I do not mean by this to minimize the problems that will undoubtedly be faced in the development of other components of the system, but I believe that the crucial pacing and determining part of the nuclear rocket will be the achievement of successful reactor operation.

The first nuclear-rocket reactors have been undergoing tests in the KIWI program. Thus far, six KIWI reactor tests have been run at nuclear power. The first three of these were part of the KIWI-A series, and the last three were part of the KIWI-B program aimed at developing a basic core design that could be engineered for flight application. The last two power experiments were run using liquid hydrogen as the coolant with a regenerative, liquid hydrogen cooled jet nozzle. Important results were obtained in these tests to indicate that the method of reflector drum control is an effective one and that the reactor can be started in a controlled manner with liquid hydrogen. Other general results on the neutronics, materials, design assumptions, etc. were obtained. However, reactor damage has been encountered. In the last power test run on November 30 of last year, the KIWI-B4A reactor, which has been and is our favored basic design for flight development, encountered vibrations early in the test run. Examination of the reactor indicated cracking in almost all of the fuel elements and damage to certain thermal insulation components surrounding the core.

You may ask how I can be so confident of developing a suitable nuclear rocket technology in the face of this damage that has shown up in the development of the nuclear rocket reactor. I am convinced that these troubles are in the area of mechanical engineering design. Their solution is susceptible to the normal engineering development processes used on any mechanical system. The fact that neutrons exist provides simply another design environmental condition but does not make the reactor a magical black box to be handled as something different from any other mechanical system.

I am convinced that one of the major problems in our program to date has been insufficient analysis and testing of all of the components and subsystems under conditions that simulate as closely as possible the conditions that will exist in the reactor. It is, of course, true that it is difficult to simultaneously duplicate all conditions. However, I believe the preparation of appropriate test equipment and simulation facilities, even if complex and costly, is justified by the increased probability of successful development of this important technology. Where simultaneous simulation of environmental conditions is not possible, then preliminary testing under partial environmental conditions is better than none at all, if a suitable analytical model is developed and used to evaluate the results obtained. When we consider the hundreds of millions of dollars in environmental simulation and test facilities that have been spent in the aircraft and space area so far for wind tunnels, vacuum chambers, centrifuges, dynamic stands, space simulators, and component facilities, we realize that this is not a new concept.

At the very start of the nuclear rocket program, however, it was decided that full reactor tests were the best way of simulating all effects that would be experienced in the reactor. The program emphasized this point to the extent that, I believe, the pressure of full power tests and of meeting tight, self-imposed schedules for such tests resulted in bypassing important preliminary development steps and resulted in insufficient thought on the development of means of testing all of the parts of the systems under simulated conditions. This point is obviously made in retrospect, but it serves as a basic guide in our program now.

I think a good indication of this fact is demonstrated by the results of our recent tests on a cold reactor having no uranium at all, which was run to help explain the results in our November power tests. In this reactor, the fuel elements were replaced by unloaded graphite. The tests were run with nitrogen, helium, and hydrogen gas flows with pressure drops through the reactor similar to those that exist during a normal reactor startup. Vibrations were encountered during those tests similar to the ones that were experienced in the power run on the KIWI-B4A reactor made last November. Considering the difference in cost of materials (no uranium and far cheaper fuel element costs) and labor and time, we estimate the tests of May 15 were probably on the order of $2 million cheaper than the power run on the KIWI-B4A. I also believe much more information was obtained during that test than during the KIWI-B4A test of last November. I think this is a good indication that partial simulation is better than none and in a development program where understanding must be an essential goal, it may, at certain times, be better than the full power operation.

The present program is being expanded to include all of the detailed, simulated, component and subassembly flow and mechanical tests that are required in the development of any piece of mechanical equipment. In addition, full reactor tests under cold gas conditions and cold liquid and vibration tests will be included. All of these tests may provide a veto on the running of any power reactor test, but power tests are obviously an essential part of any program as a demonstration of successful operation and as a means of duplicating all ground operating conditions of the system simultaneously. I am convinced that such a thorough development approach will lead to successful reactor operations.

It must, however, be recognized that, as is the case in every development program, no individual reactor test should be expected to prove itself completely satisfactory until we have passed quite a large number of tests. Problems may reveal themselves in the component test and simulated environment test effort. Problems may be revealed in the next power tests. All of these will result in changes in design aimed at solving the problems that are revealed. This is the normal course of events in a development program and should not be considered unusual in this case.

When sufficient confidence exists that the reactor is well along in development toward the achievement of a satisfactory design, then the major hardware development on the NERVA engine and the RIFT stage will proceed. I have no question that every other component required in the engine system can be developed. I have further been assured by all of our vehicle people that the RIFT vehicle is much simpler than any other rocket vehicle so that technology certainly will not be the pacing element.

In the course of development of the nuclear rocket I hear some, who generally have other systems to sell, predict the failure of the systems with which we are working. They question fuel elements, strength, life, corrosion, structure - anything that will make the as yet totally unevaluated paper design sound better than the one that is under development. The desire to sell frequently results in a paper design based on a trivial and inadequate amount of research information that has every virtue one can quote. It recalls words attributed to Admiral Rickover sometime back. He is quoted as having said "..... the academic reactors have none of the performance failures or faults of the real ones ....." In most cases, unfortunately, these salesmen of paper designs try to sell a system development rather than a logical program of accumulation of the information upon which any rational design and development must be based.

However, this does not absolve us of our responsibility to undertake promising backup reactor work in a program of such size and importance. For that reason, we are conducting work aimed at accumulating such basic information with tungsten and we are also undertaking conceptual design studies of various alternate graphite reactors. These systems are, however, several years behind the graphite system on which we are now working. It will probably take two years of good solid work before we are ready to undertake a full-fledged reactor development based on tungsten technology. It would probably be at least four years or more likely five years before a tungsten reactor power test could be run.

In general, I am convinced that we can make the nuclear rocket technology available for use in a wide variety of missions. Nuclear rockets are being thoroughly investigated and researched. They are the next logical, large step jump in specific impulse. I am convinced that we will rely on them in all of the missions that we perform beyond those that are now programmed.

We should also consider where electric propulsion, Orion, and the gaseous reactor rocket systems may be used. I would like to spend a little time discussing these systems. It is obviously important for this country to carefully consider and evaluate the different systems that are proposed in order to try to assure that it is working on systems that will prove feasible, useable, and developable, and will have sufficient performance potential to make them interesting.

On paper, all three of these advanced systems offer substantial performance potential. If electric power generating systems weighing in the neighborhood of 10 pounds per kilowatt can be developed to operate for over a year with good reliability, then electric propulsion might compete with the nuclear rocket for the manned Mars mission. Electric powers of 20 to 40 megawatts would be required for such a mission. With men on board, some maintenance on the power supply might be possible, thereby helping to ease a bit the extreme performance and life requirements imposed on unmanned electrically propelled systems. It must, nevertheless, be recognized that the development of systems weighing 10 pounds per kilowatt and capable of delivering 20 to 40 megawatts electrical for very long periods may not be achievable. A strong research and advanced technology development program is now under way to try to accumulate the information necessary to determine the feasibility of the performance objectives I have just listed. I believe that the data obtained so far, although very meager, combined with the performance potential of electric propulsion for missions beyond Mars, including difficult instrumented missions to the more distant planets, and the need for large amounts of on-board, auxiliary electric power justify the technology development effort that is under way.

Another system that is being strongly boosted for missions to the planets and into deep space or for missions involving large velocity increments due to maneuverability requirements, is the Orion concept. You will recall that this is the concept in which a succession of many, small nuclear explosions are used to propel a large spaceship. I used the word "ship" rather than "craft" because the protagonists for this system talk in terms of heavy ship building construction and assembly methods. There is naturally much enthusiasm about the performance potential that has been calculated for this system. It is however, uncertain as to how close to this performance potential one can really get. It is my personal opinion that nuclear tests are essential if any meaningful results are to be obtained to answer any questions on actual performance potential and feasibility. Although these would start as single nuclear shots, they would very quickly have to expand to many tests in rapid succession and would probably have to be done in space to be meaningful. Herein lies the problem as I see it. As I have indicated earlier, it is my opinion that if a system is to be relied upon and is to be successfully developed, it must be possible to break the system down into components that may then be evaluated under environmental conditions simulating in essential parts the environmental conditions that it will see in the flight system. These components must then be put together in subassemblies and thoroughly tested, analyzed, and evaluated. Finally, they must be assembled into the system and thoroughly tested on the ground. It is, in my opinion, essential that a system be able to go through such a ground development program if it is to be a feasible system. I do not believe that Orion is such a system. I have seen no such test or development program plan. I have seen no plan for the development of simulation facilities in which to test components, subassemblies, and assemblies under the space flight environmental conditions. It is always proposed that the system will be developed in flight. I think this is nonsense. It requires that the country make the commitment of all of the funds required before it has ever demonstrated what the system can do or that it can do anything. I know of no system that has been developed in flight and I am personally convinced there will never be such a system development. Flight tests are, of course, used in development as a check to insure that the space flight environment does not adversely affect the already determined performance of the system. In some cases, as, for example, the Saturn I first stage, the flight tests become a demonstration of the suitability of the system. I believe that every effort must be made to make the flight test a demonstration of suitable operation. If suitable ground tests cannot be prepared, if ground test facilities cannot be prepared, then, in my opinion, the system is not developable. I have come to the conclusion, after much though on Orion, that with all of its calculated performance potential, it is not feasible because it is not developable. Developability is as important in judging feasibility as is the need for assurance that a concept does not violate any basic physical principles.

In the gaseous and cavity reactor rocket systems, we again have a theoretical high performance potential. In these systems uranium is held in a gaseous state so that extremely high temperatures and high specific impulses may be achieved as hydrogen is heated by the fission process through various heat transfer processes. There are today no conceptual designs that can be considered practical. There are still very large gaps in basic understanding of the extremely high temperature processes that are involved in this concept. Basic work on high temperature heat transfer and physics is, therefore, required and is being, at least, partially supported. It is my opinion that much of the basic work done for this program can be considered to add to the fund of scientific knowledge that may one day find application in other areas and can be justified from that point alone. It is, however, important that concentrated thinking go into the developability of this system before major dollars are invested. There is no question that the extremely high temperatures involved make an accumulation of understanding of the operating characteristics and the development of component parts of the system extremely difficult. One of the difficult features to simulate in the solid fuel element nuclear rocket reactor is the heat energy generated in this system. This problem will be increased many fold in any cavity or gaseous reactor system. Very sound thinking must, therefore, be directed toward evaluating the methods that can be used in the development of such a system and in understanding such a system for the various potential concepts that have been considered. The basic question, "How do we test and develop?" must be one factored into the evaluation of feasibility of any concept proposed. I am afraid that that has not been done sufficiently in many of the advanced areas that are being proposed.

I have tried today to give a very frank assessment of where I think we stand in the area of propulsion for advanced missions. All of these systems rely on nuclear energy but not all of them have the same potential for use and development. I know that my words will sound sour to some people. However, I believe that in meeting the challenge in this space age and in establishing our preeminence in this program, the country must carefully determine those areas that provide the greatest promise for assuring continued progress in our abilities to travel and explore in space. Within the practical considerations of budget and manpower an indiscriminate effort that puts equal weight on all things will result in no accomplishments. It is essential that just as we exercise discrimination in the space missions that we undertake, we must exercise discrimination and realism in the research and advanced technology development that we undertake. It is only through careful technical evaluation and assessment of all of the factors involved in the development of advanced systems that a sound, forward looking program of real accomplishment will result.

I urge that all of you also try to make this kind of an assessment thoughtfully and objectively. Our country will benefit from such objectivity.